~~Kaiser Hughes~~ 5/1

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SOME LIFT AND DRAG MEASUREMENTS OF TWO CONFIGURATIONS OF A NACELLE AND OIL-COOLER SCOOP FOR THE HUGHES-KAISER CARGO AIRPLANE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Department of Commerce

SOME LIFT AND DRAG MEASUREMENTS OF TWO CONFIGURATIONS OF A NACELLE AND OIL-COOLER SCOOP FOR THE HUGHES-KAISER CARGO AIRPLANE

By John H. Quinn, Jr.

SUMMARY

Tests have been made in the NACA two-dimensional low-turbulence tunnel to determine the drag characteristics of two configurations of a 0.0476-scale nacelle and oil-cooler scoop for the Hughes-Kaiser cargo airplane. These nacelles were mounted on the Hughes-Kaiser wing section 577.325 (NACA 63,4-4(20.2) approx.). For comparison, one nacelle was tested on a thick conventional airfoil (NACA 23021). These tests were carried out at a wing Reynolds number of 2.5 million.

These nacelles had a slightly favorable effect on the maximum lift coefficient. The drag increment of the nacelles was slightly less on the low-drag section than on the conventional section.

INTRODUCTION

Tests have been made previously in the NACA two-dimensional low-turbulence pressure tunnel to obtain lift and drag data for bomber nacelles mounted on low-drag wings (references 1, 2, and 3). In these tests the ratio of nacelle diameter to wing thickness ranged from 1.0 to 2.5. The trend toward very large airplanes, with engine dimensions remaining fixed, may lead to designs exemplified by the Hughes-Kaiser cargo airplane where the nacelle diameter approaches the value of one-half the wing thickness. Such trends have led to questions concerning the effects of small nacelles on relatively thick wings.

The purpose of this investigation was to determine the effects of two 0.0476-scale nacelle and oil-cooler scoop configurations for the Hughes-Kaiser cargo airplane on the lift and drag characteristics of the Hughes-Kaiser wing section 577.325 (NACA 63,4-4(20.2) approx.). For comparison, one nacelle was tested on a conventional airfoil of approximately the same thickness as the low-drag section. These tests were carried out in the NACA two-dimensional low-turbulence tunnel at a wing Reynolds number of 2.5×10^6.

SYMBOLS AND NOTATIONS

The increment of drag of a nacelle is defined as the difference between the drag of the wing-nacelle combination and the drag of the plain wing. Symbols used are defined as follows:

A_e exit area

A_n entrance area

V_e exit velocity

V_n entrance velocity

V_o free-stream velocity

ΔH total pressure loss at exit

q_o free-stream dynamic pressure

R_w wing Reynolds number

c airfoil chord

A_c area upon which drag increments are based (airfoil chord squared)

$\Sigma \Delta c_{d_c}$ coefficient of total drag increment of nacelle including drag due to internal losses

$c_{d_{c_i}}$ coefficient of drag due to internal losses, calculate from the formula:

$$c_{d_{c_i}} = 2 \frac{A_e}{A_c} \frac{V_e}{V_o} \left[1 - \left(1 - \frac{\Delta H}{q_o} \right)^{\frac{1}{2}} \right]$$

Δc_{d_c} coefficient of external drag increment $\left(\Sigma \Delta c_{d_c} - c_{d_{c_i}}\right)$

MODELS AND METHODS

The wings used in this investigation were 2-foot-chord models of the NACA 63,4-4(20.2) and NACA 23021 airfoil sections. Both these models were constructed of wood with laminations running chordwise, and were prepared for test by the methods described in reference 4. The nacelles and scoops were also constructed of wood. Sketches of the nacelles and scoops showing the internal duct arrangement and the position of the baffle plates used to approximate pressure losses due to an engine or oil cooler are shown in figures 1 to 4. Nacelle B has a larger radius of curvature near the leading edge of the cowling than nacelle A, and the spinner is less pointed. Scoop B, which is about 20 percent longer than scoop A, has a more rounded gutter and a larger radius of curvature on the lower surface. Entrance and exit areas for both nacelle-scoop combinations are given in the following table:

Nacelle	Scoop	A_n (sq in.)	A_e (sq in.)	A_e/A_n
A		1.304	0.545	0.418
B		1.202	.581	.484
	A	.440	.160	.364
	B	.500	.220	.440

The ratio of the nacelle diameter to the wing thickness was 0.569 for the NACA 63,4-4(20.2) and 0.548 for the NACA 23021 section.

For each wing the nacelles were horizontal at a section lift coefficient of 0.8. The angle of incidence between the nacelle center line and wing chord line was -4.5° when mounted on the NACA 63,4-4(20.2) section and -7° on the NACA 23021 section.

The nacelle and scoop-drag increments were found from force measurements. Section drag coefficients were obtained by the wake-survey method as described in reference 4. Section lift coefficients were obtained by integrating pressures along the tunnel floor and ceiling. All lift and drag coefficients are corrected for tunnel-wall interference.

Three nacelles of type A, spaced 12 inches on centers, were tested on both wings. The increment of three nacelles divided by three is in good agreement with the increment of one nacelle alone. Since the accuracy is increased by measuring a larger quantity, the drag increments shown for nacelle A are averages of the increment for three nacelles.

Pressures at the exits were measured by small static and total pressure tubes placed at several positions around the exit.

All drag increments shown are external increments, Δc_{d_c}, and are based on a model area equal to the chord squared.

Both airfoils were tested at a lift coefficient of about 0.6 with a 1-inch by $2\frac{3}{4}$-inch roughness strip at the center of the leading edge. This strip was composed of 0.010-inch average diameter carborundum grains cemented to scotch tape, which in turn was applied to the airfoil. The $2\frac{3}{4}$-inch length, equal to the nacelle diameter, was parallel to the span of the airfoil. This test was made to compare the drag of the nacelle with the drag of a rough spot covering the same span as the nacelle.

RESULTS AND DISCUSSION

In figure 5, external drag increments of configurations A and B of nacelle and scoop are presented as a function of lift coefficient. While the value of drag appears to be almost the same for each nacelle, type A has a larger low-drag range. Through most of the range of lift coefficients the drag increment due to scoop B has so small a value that it approaches the limit of experimental accuracy. It appears that scoop B has lower increments than scoop A throughout the range tested.

The coefficients of external drag increments of type A nacelle on each airfoil section are given in figure 6. While the increments are substantially the same on both wings, it seems that the trend is toward slightly smaller increments on the low-drag section. The drag increments based on an area equal to the chord squared for the rough spot on each wing are shown in figure 6. It will be noted that the additional drag caused by the rough spot is the same as the increment of the nacelle on the low-drag wing, but that the rough spot results in approximately one-third the drag caused by the nacelle on the conventional section.

In figure 7, section drag coefficients and section drag coefficients plus drag increments due to nacelle A are plotted against lift coefficients for both airfoil sections. The shaded areas represent the additional drag due to the nacelle.

Section lift coefficients as a function of angle of attack are presented in figure 8 for each wing alone and for each wing with type A nacelle. At low and moderate values of the lift coefficient the nacelle appears to have no effect on the lift curve. There is, however, a slight favorable effect upon maximum lift.

Internal flow characteristics throughout the range of lift coefficients for both nacelle and oil scoop configurations are presented in figures 9 and 10.

CONCLUDING REMARKS

The increment of drag due to a small nacelle having a diameter about equal to half the wing thickness was slightly less on the NACA 63,4-4(20.2) than on the NACA 23021 airfoil section.

Small nacelles mounted on a low-drag airfoil section appeared to have a slightly favorable effect on the maximum lift coefficient.

Type A nacelle, which incorporates a larger cowling nose radius than nacelle B, had the larger low-drag range. Type B oil-cooler scoop, with rounded gutter and larger radius of curvature on the lower surface, had a smaller drag increment than type A.

Nacelle A and scoop B mounted on the NACA 63,4-4(20.2) section probably would result in a lower over-all drag than any of the combinations tested.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 14, 1943.

REFERENCES

1. Ellis, Macon C., Jr.: Some Lift and Drag Measurements of a Representative Bomber Nacelle on a Low-Drag Wing. NACA C.B., May 1942.

2. Ellis, Macon C., Jr.: Some Lift and Drag Measurements of a Representative Bomber Nacelle on a Low-Drag Wing - II. NACA C.B., Sept. 1942.

3. Ellis, Macon C., Jr.: Effects of a Typical Nacelle on the Characteristics of a Thick Low-Drag Airfoil Critically Affected by Leading-Edge Roughness. NACA C.B. No. 3D27, 1943.

4. Jacobs, Eastman N., Abbott, Ira H., and Davidson, Milton: Preliminary Low-Drag-Airfoil and Flap Data from Tests at Large Reynolds Numbers and Low Turbulence, and Supplement. NACA A.C.R., March 1942.

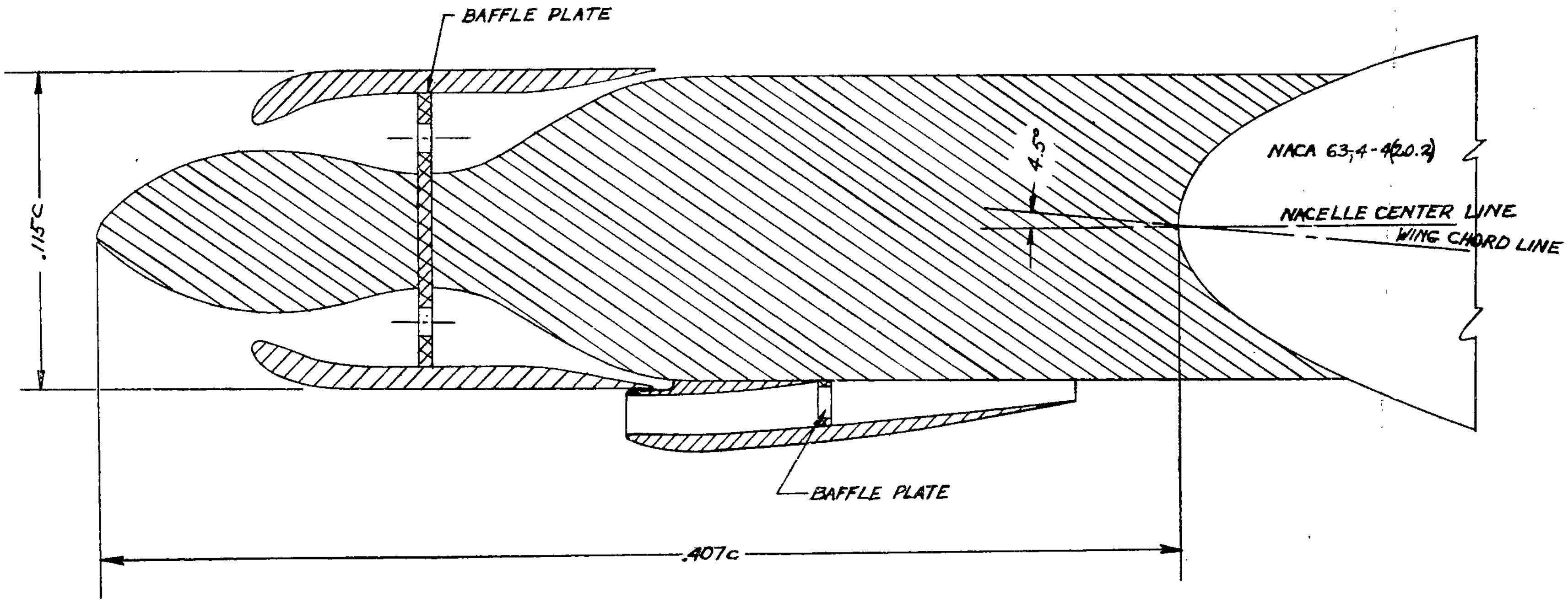

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Figure 1.- Section through centerline of nacelle and scoop, configuration A.

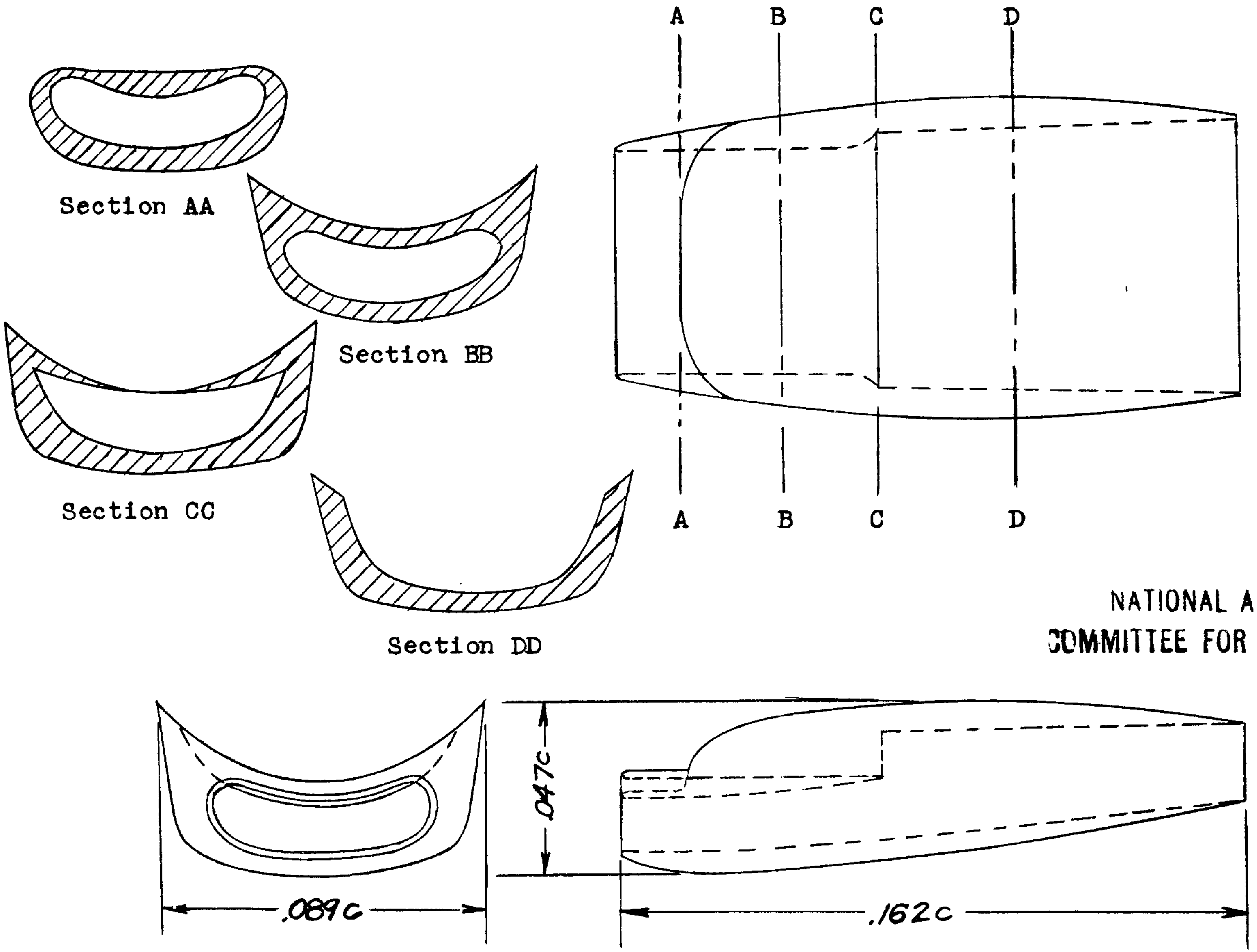

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Figure 2 .- Contour of oil scoop A.

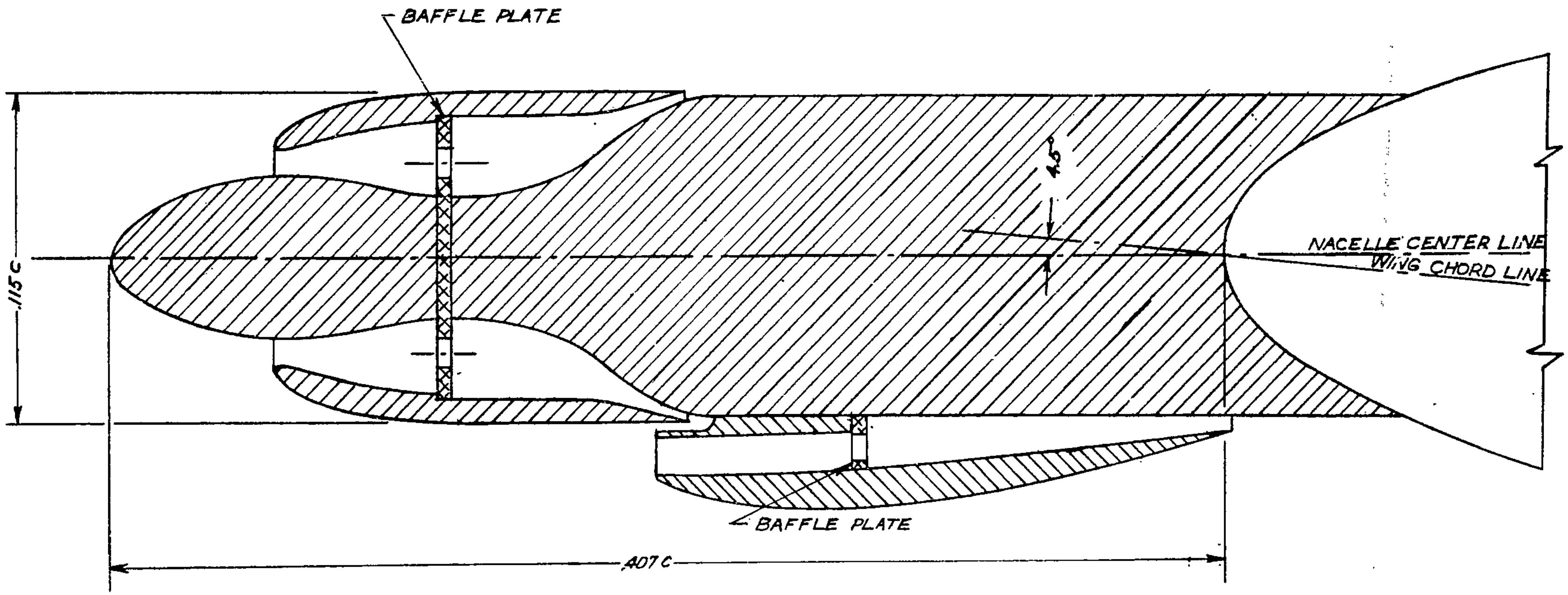

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Figure 3.- Section through centerline of nacelle and scocp, configuration B.

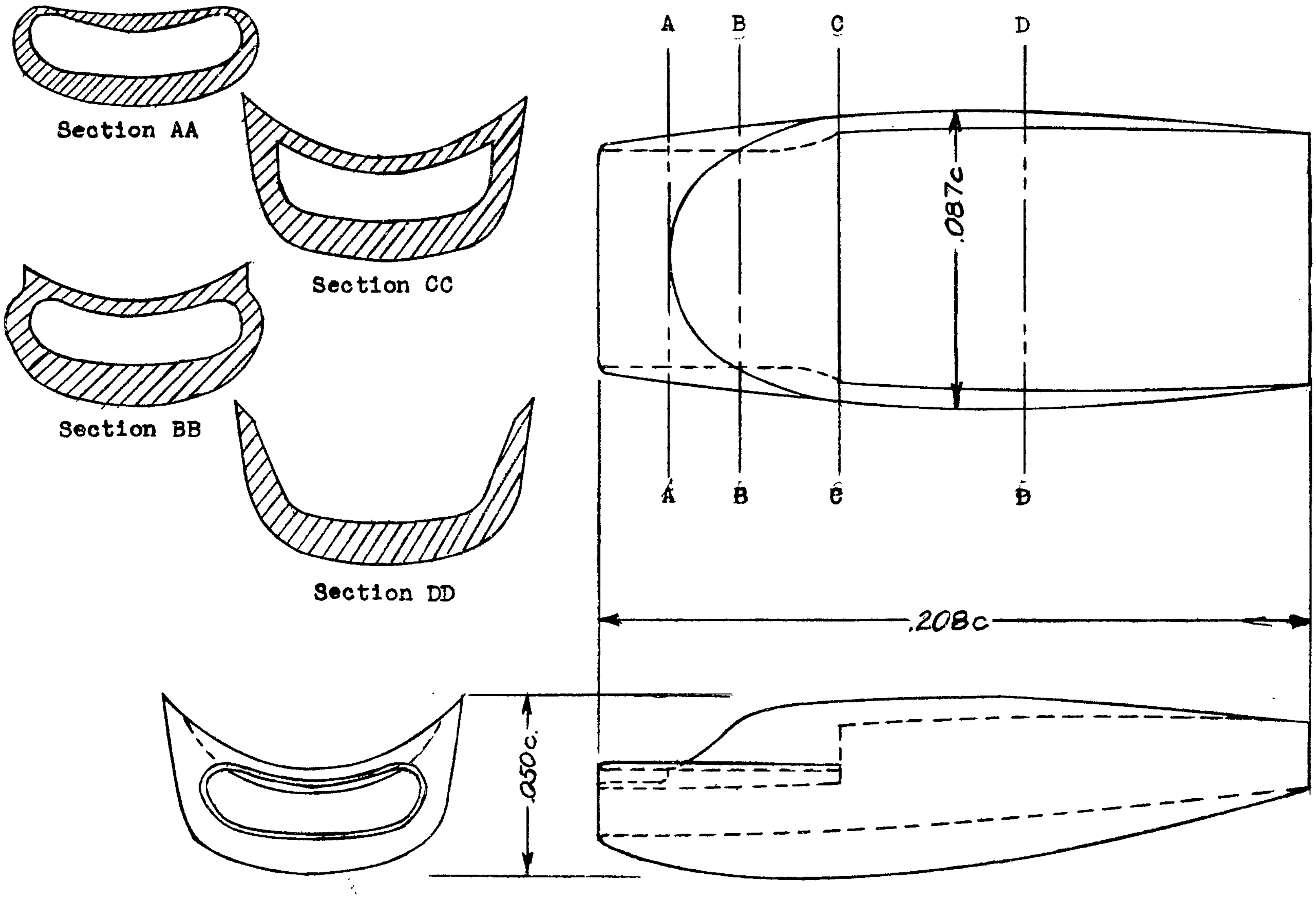

Figure 4.- Contour of oil scoop B.

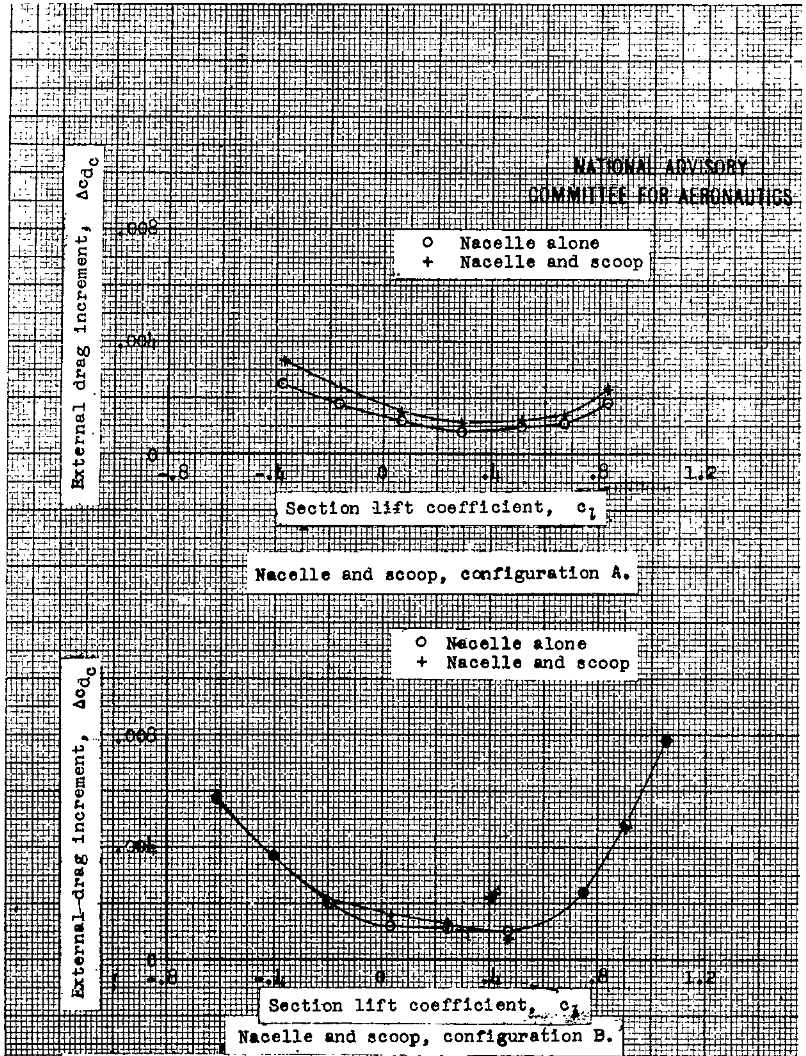

Figure 5.- External drag increments of nacelle and oil scoop, configurations A and B, on NACA 63,4-420.2 airfoil section. R_w, 2.5×10^6.

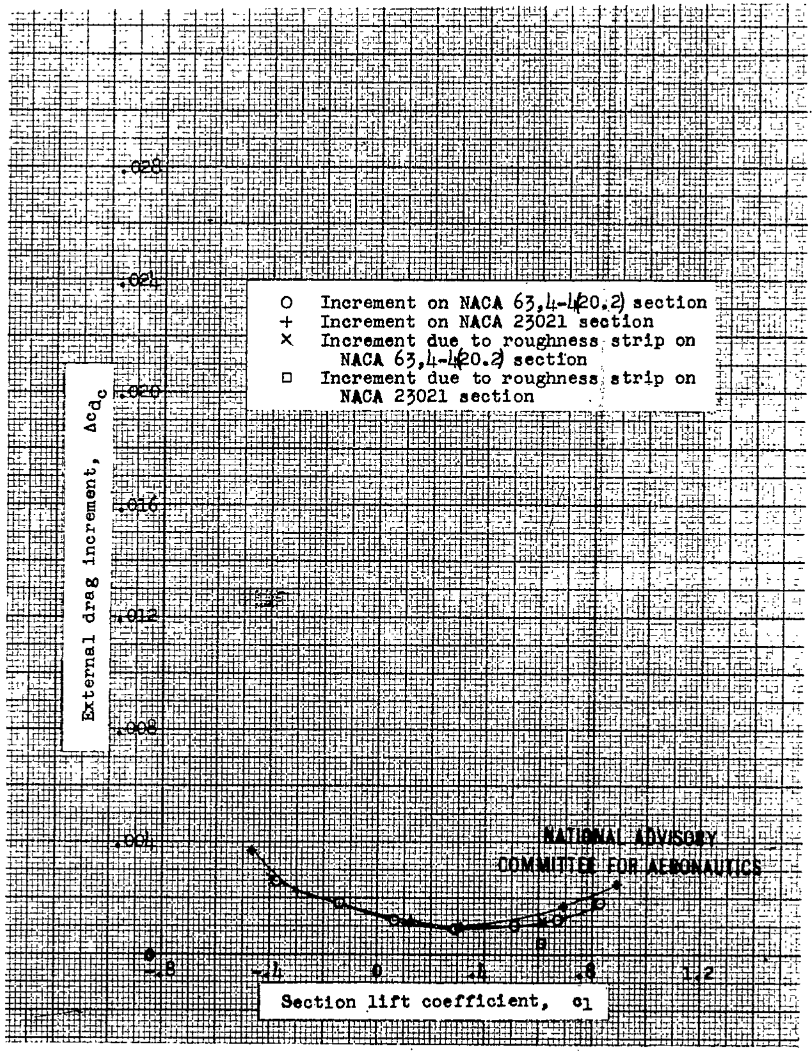

Figure 6.- External drag increments of nacelle A on NACA 63,4-420.2 and NACA 23021 airfoil sections. R_w, 2.5×10^6.

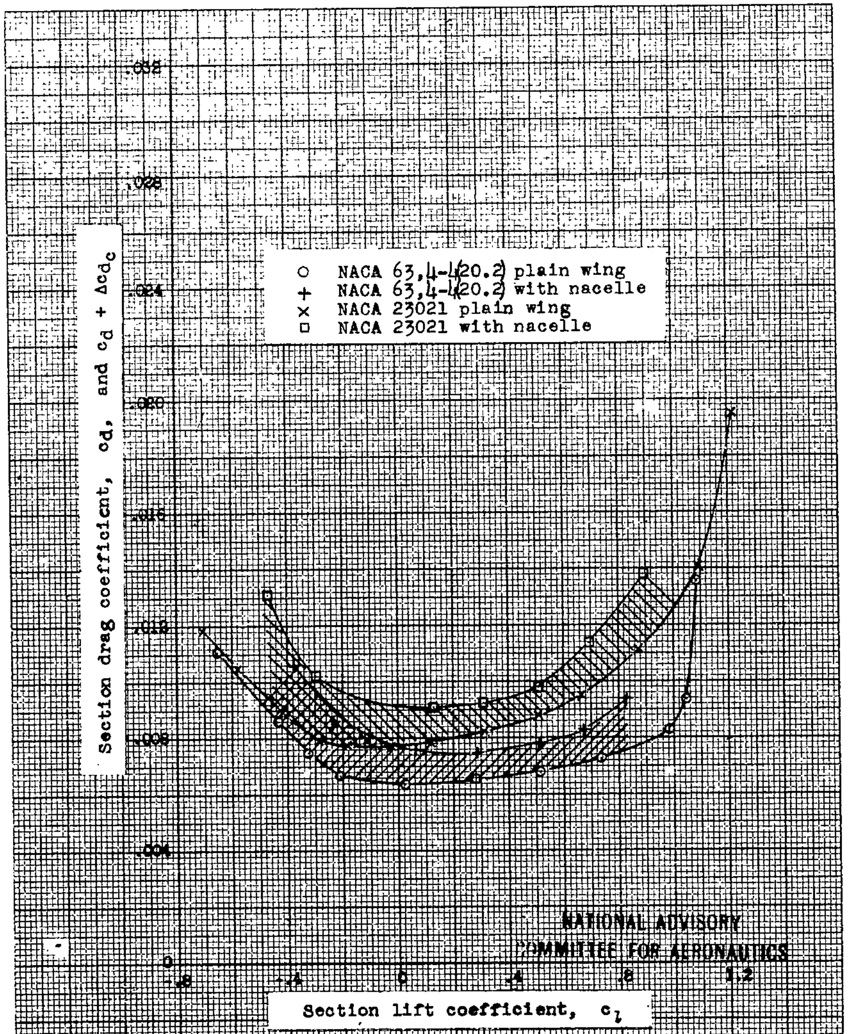

Figure 7.- Section drag coefficient and section drag coefficient plus drag increment of nacelle A on NACA 63,4-4(20.2) and NACA 23021 airfoil sections. R_w, 2.5×10^6.

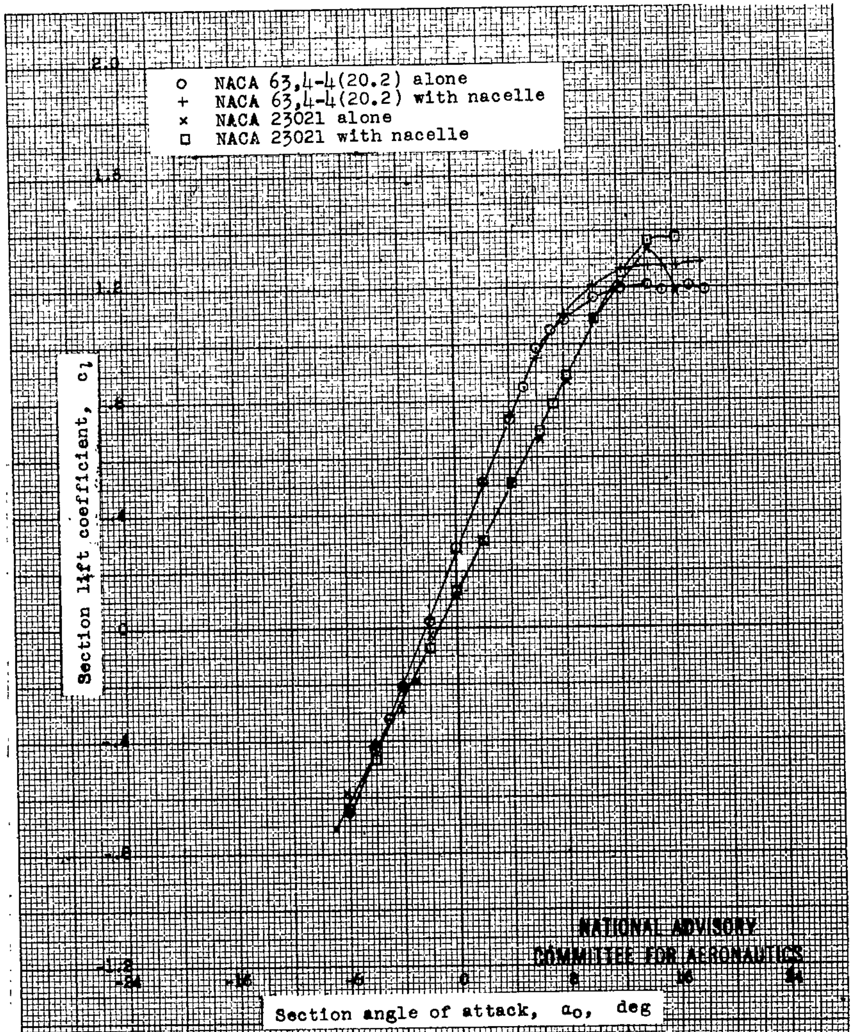

Figure 8 .- Lift characteristics of the NACA 63,4-4(20.2) and NACA 23021 airfoil sections with and without type A nacelle. R_w, 2.5×10^6.

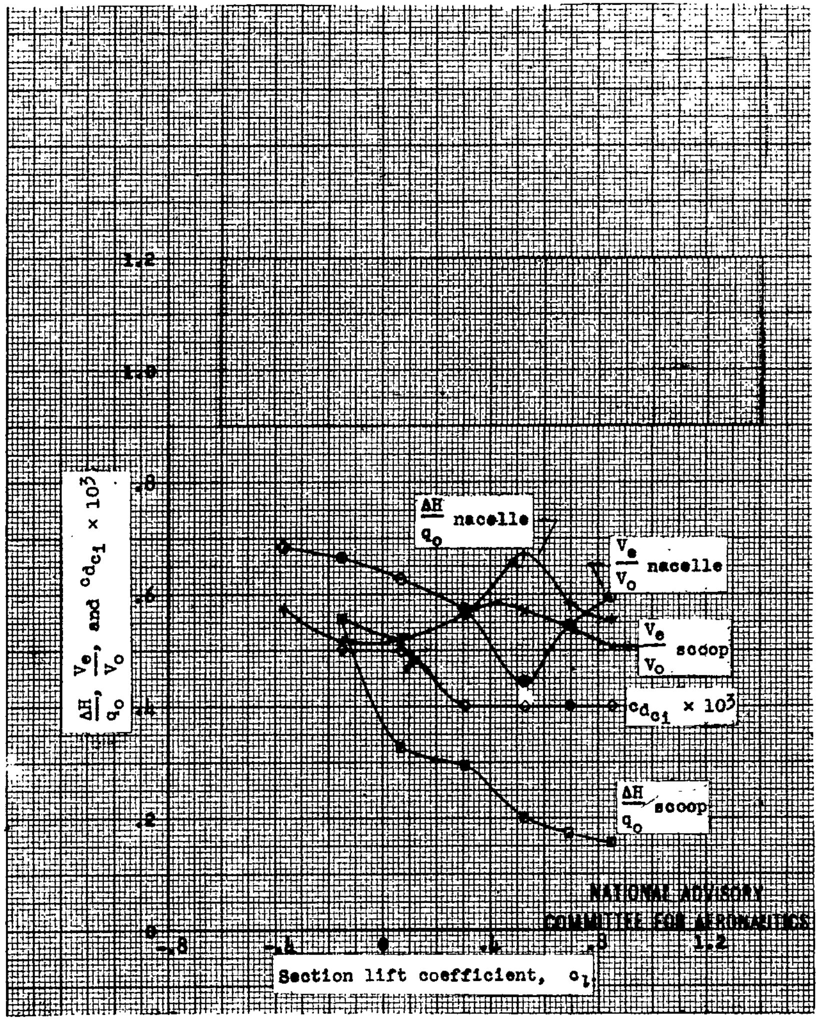

Figure 9.- Internal flow characteristics of nacelle and oil scoop, configuration A, mounted on NACA 63,4-420.2 airfoil section. R_w, 2.5×10^6.

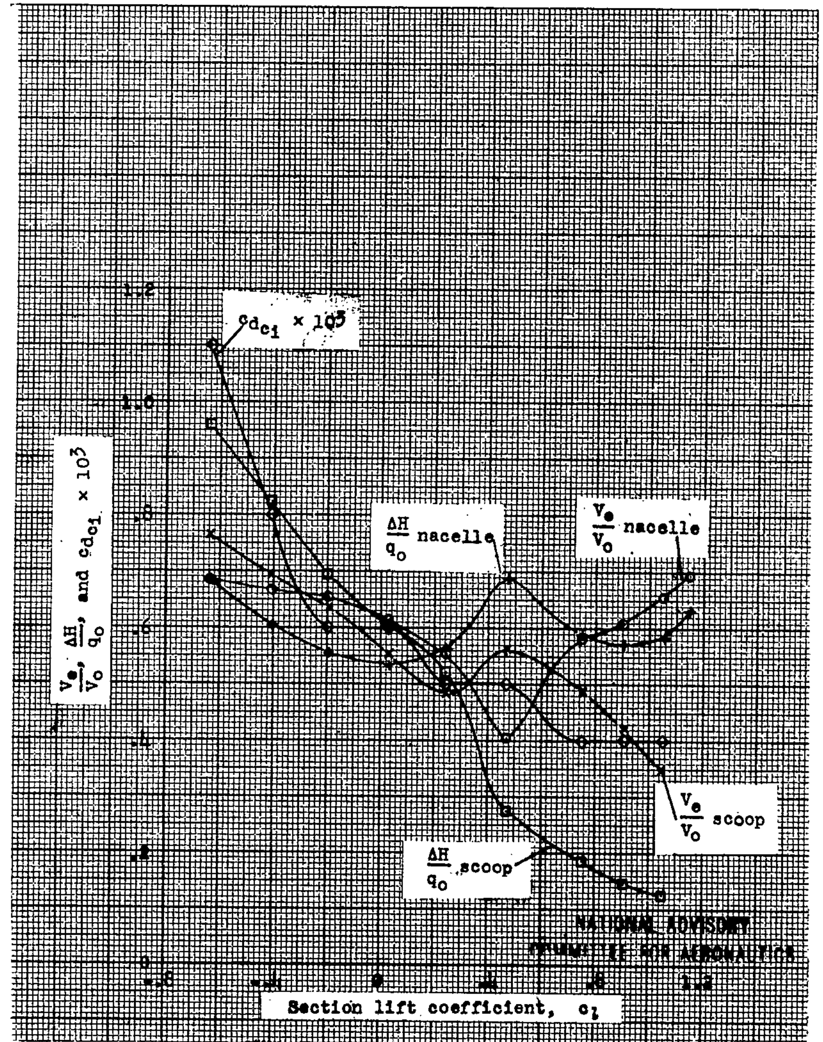

Figure 10.- Internal flow characteristics of nacelle and oil scoop, configuration B, on NACA 63,4-420.2 airfoil section. R_w, 2.5×10^6.

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